Digital Autoradiography of ^{241}Am
Spatial Distribution within Trabecular Bone Regions

George Tabatadze[†], Brian W. Miller[‡], Sergei Y. Tolmachev[†]

[†]*US Transuranium and Uranium Registries*
College of Pharmacy, Washington State University

[‡]*Radiation Detection and Nuclear Sciences Group*
Pacific Northwest National Laboratory

"Learning from Plutonium and Uranium Workers"

Significance

- Knowledge of radionuclide distribution in cortical and trabecular bone regions is critical for internal dosimetry

- Dose assessment is complicated by anatomical and physiological complexity of skeleton

Goal

- Visualization and evaluation of the radionuclide distribution within cortical bone, trabecular bone, and trabecular spongiosa

- Estimation of the ^{241}Am activity concentration using digital autoradiography

Approaches

- Application of <u>i</u>onizing-<u>R</u>adiation <u>Q</u>uantum <u>I</u>maging <u>D</u>etector (iQID)

- Application of radiochemical analysis and α-spectroscopy

- Prediction using ICRP defaults

Case 0846: Whole-Body Donation

- Chronic inhalation of ^{241}Am: 2+ y

- Estimated initial body burden: 66.6 kBq

- DTPA decorporation therapy: 7 y

- Estimated residual body burden: 26.6 kBq

- Cause of death: heart failure

- Post exposure: 41 y

- Activity in skeleton (post-mortem): 29.6 kBq

TPM-A.5 Breustedt, B: USTUR Case 0846: Modeling Americium Biokinetics after Intensive Decorporation Therapy
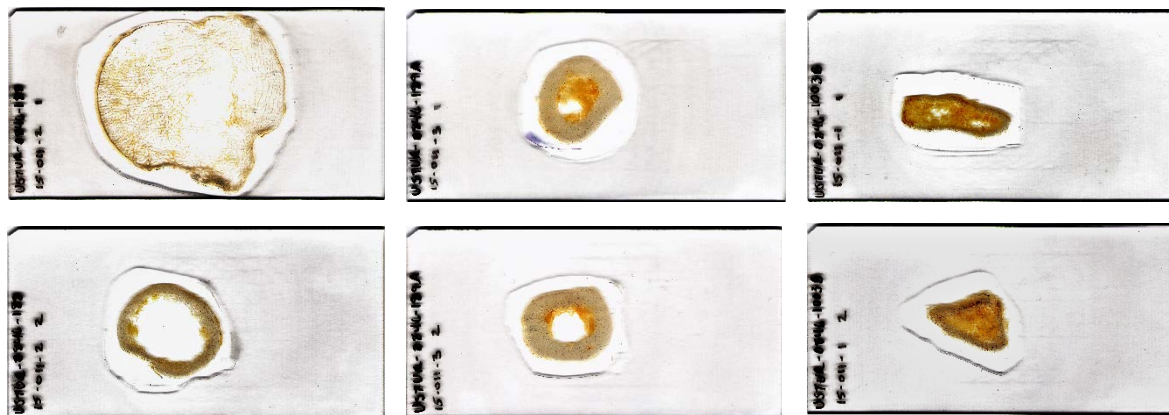
Sample Preparation: Autoradiography

- Humerus proximal end, humerus proximal shaft, and clavicle acromial end

- Plastic embedded (methyl methacrylate)

- 100-μm thick bone sections cut and polished
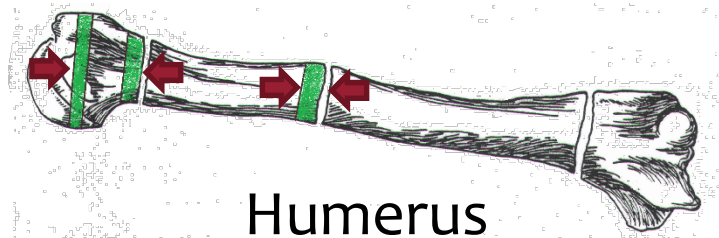
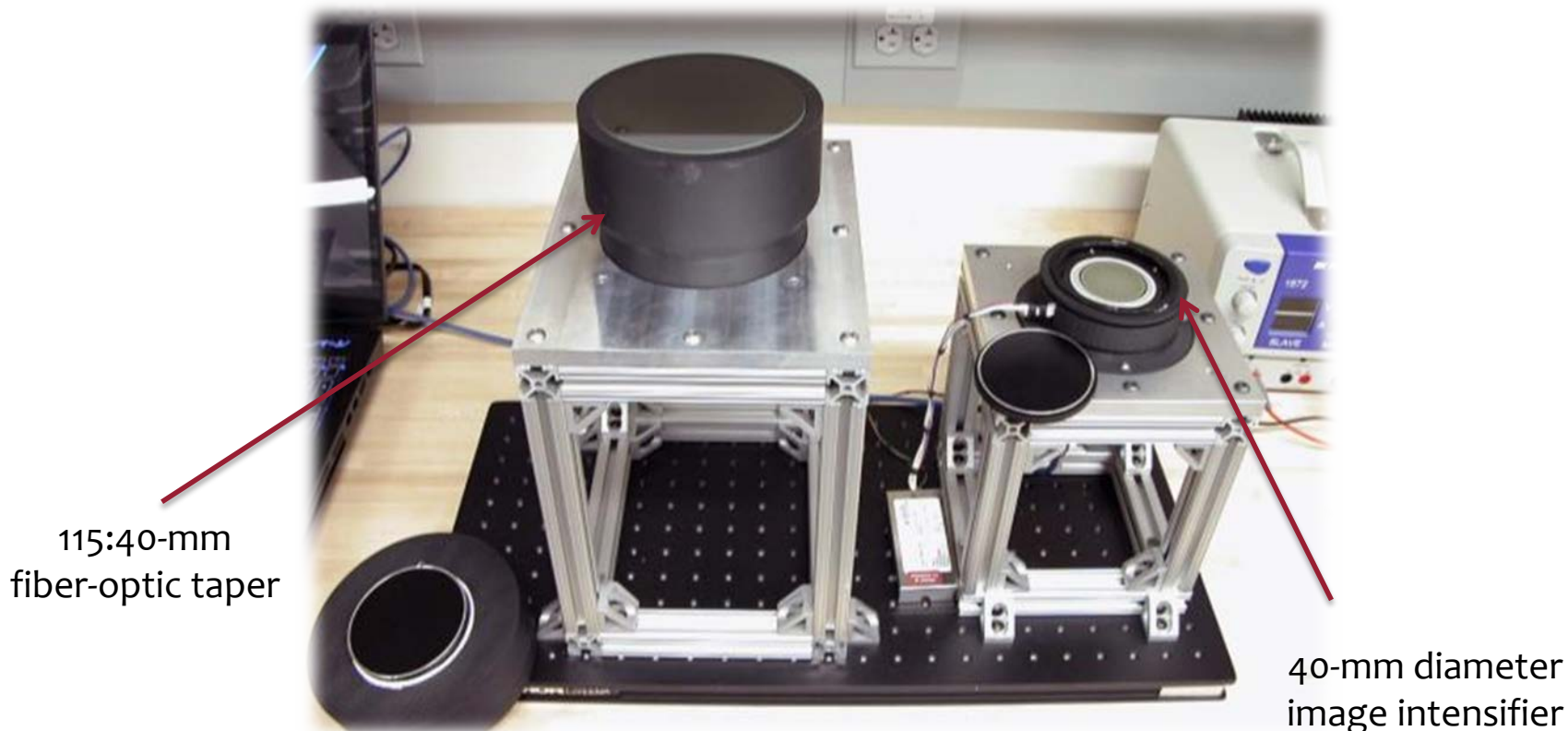Humerus   Clavicle

Counting: iQID System

- Sensitive to α- and β-particles, gammas/x-rays, neutrons, and fission fragments

115:40-mm
fiber-optic taper

40-mm diameter
image intensifier

Miller BW, Gregory SJ, Fuller ES, Barrett HH, Bradford Barber H, Furenlid LR. The iQID camera: An ionizing-radiation quantum imaging detector. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 2014(0)
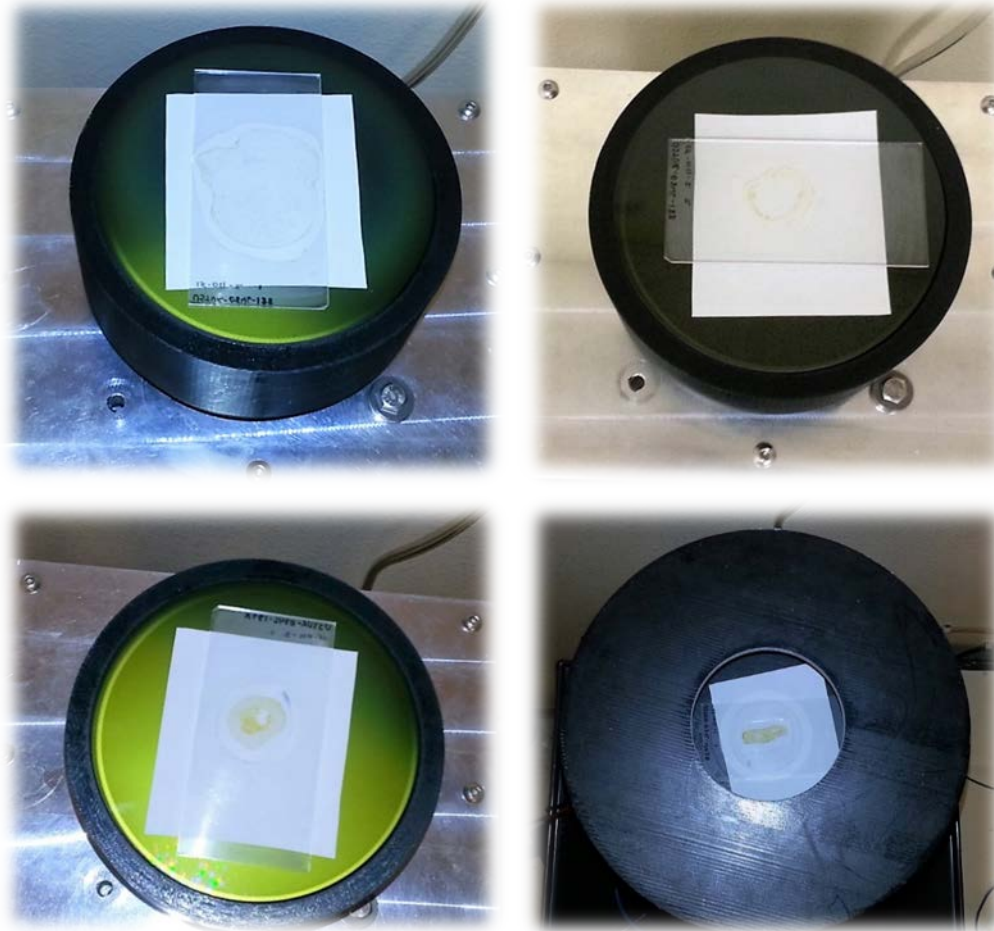
iQID: Detector Calibration

- Source: ^{242}Pu, ^{239}Pu, ^{241}Am (87 dpm, E&Z Analytics)

- High detection efficiency

  ✓ Ø115 mm detector: 93.4% (84.9% with background reduction)

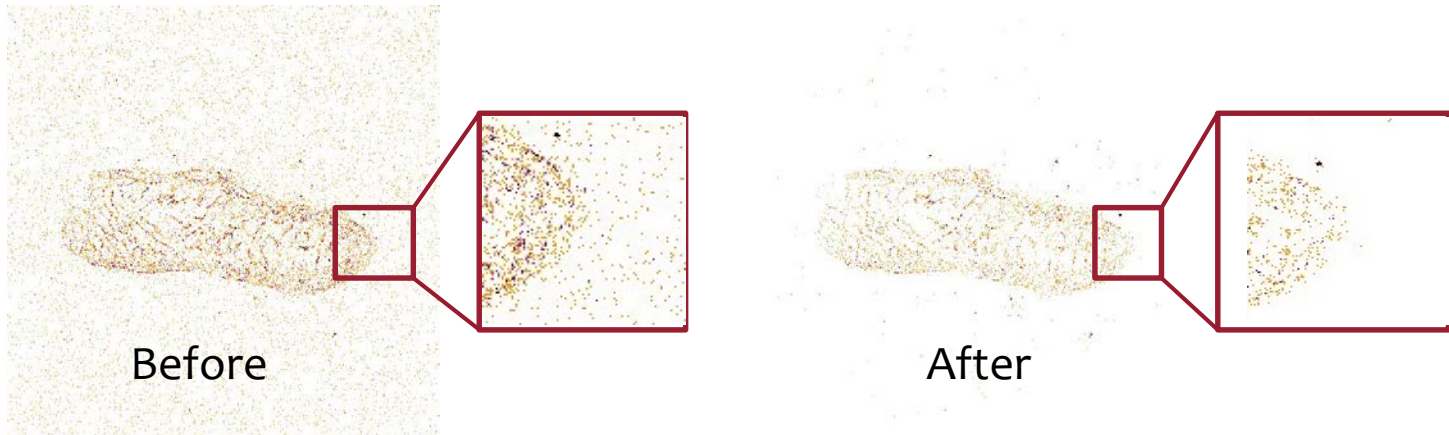 ✓ Ø40 mm detector: 92.3% (68.9%)
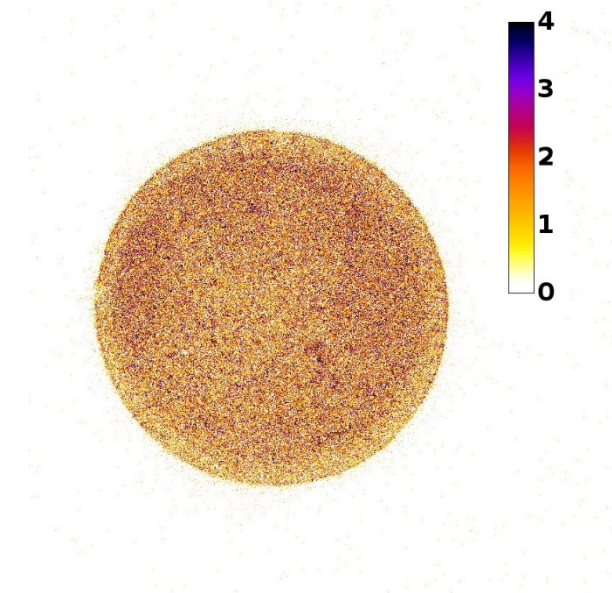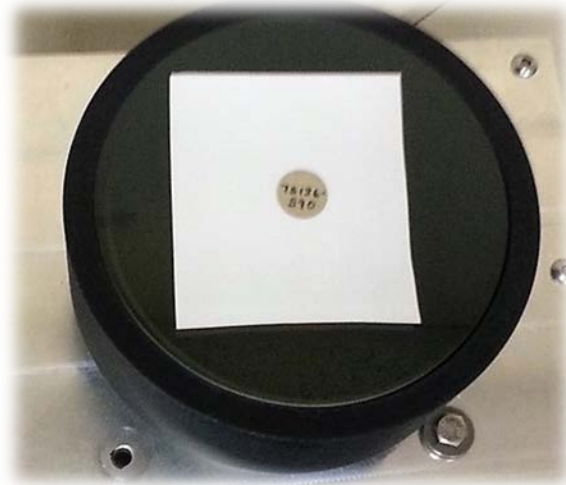
iQID: Sample Counting

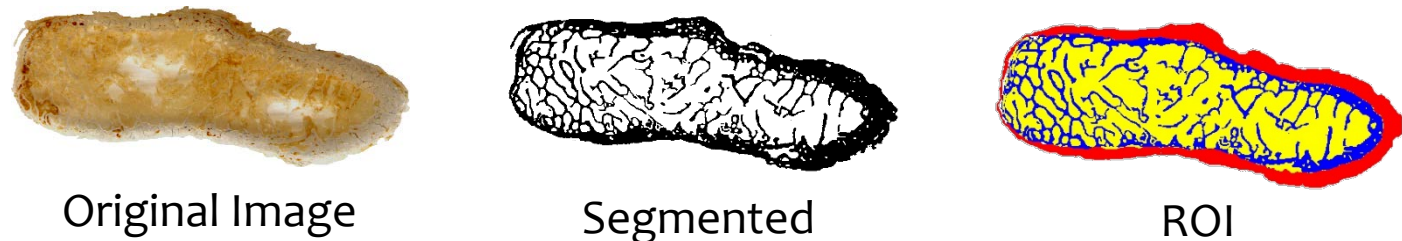- Bone samples were counted: 300 – 1,600 hours

Data Processing

- Raw iQID images were processed using MatLab® Code (Octave® software) to reduce background

Before

After

- Cortical and trabecular bone volumes were defined using Fiji® (i.e. ImajeJ®) software
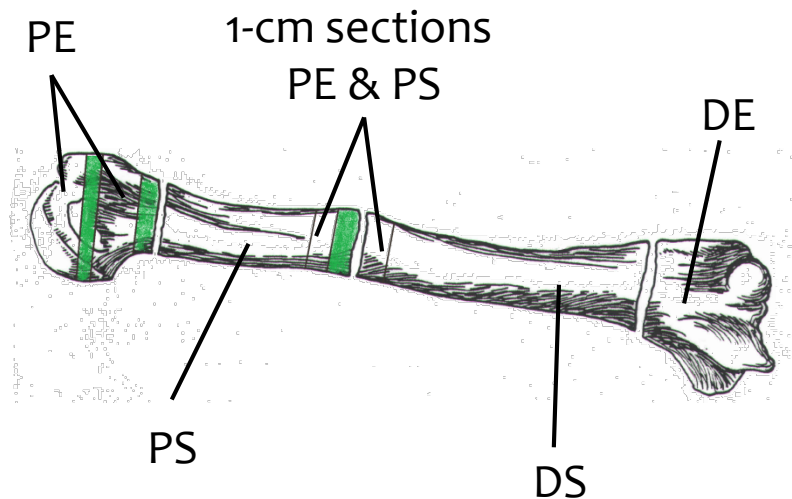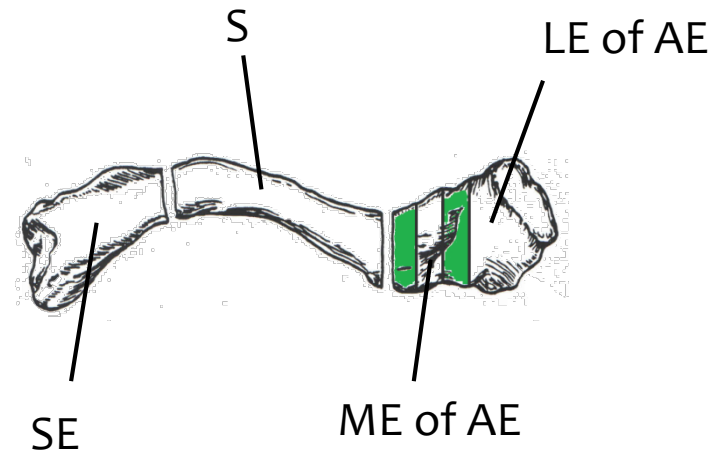

Original Image

Segmented

ROI

Radiochemistry: Sample Preparation

- Bone sections adjacent to those used for plastic embedding were selected for radiochemical analysis
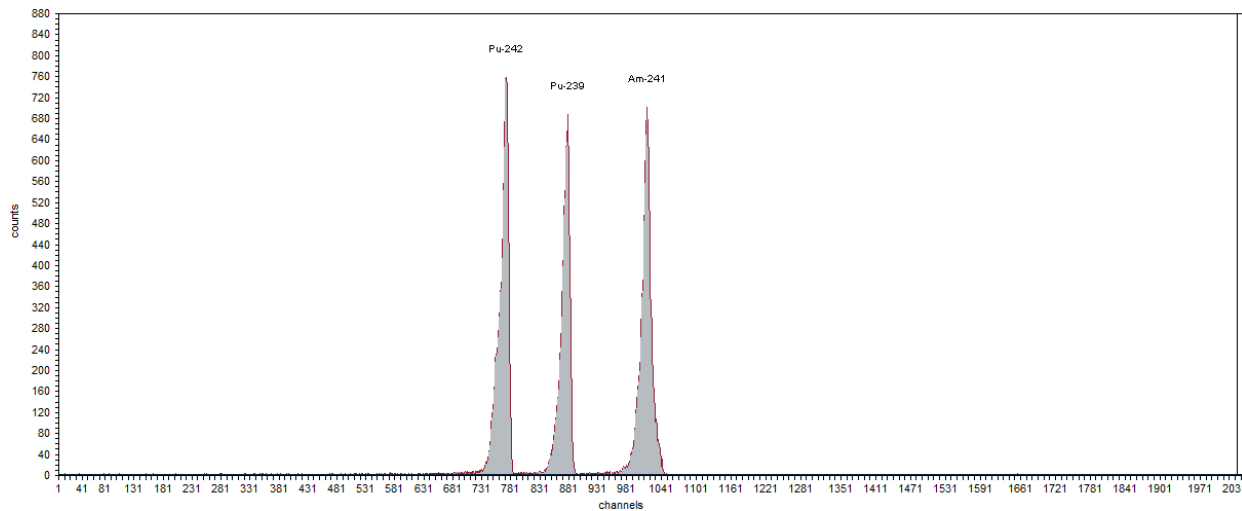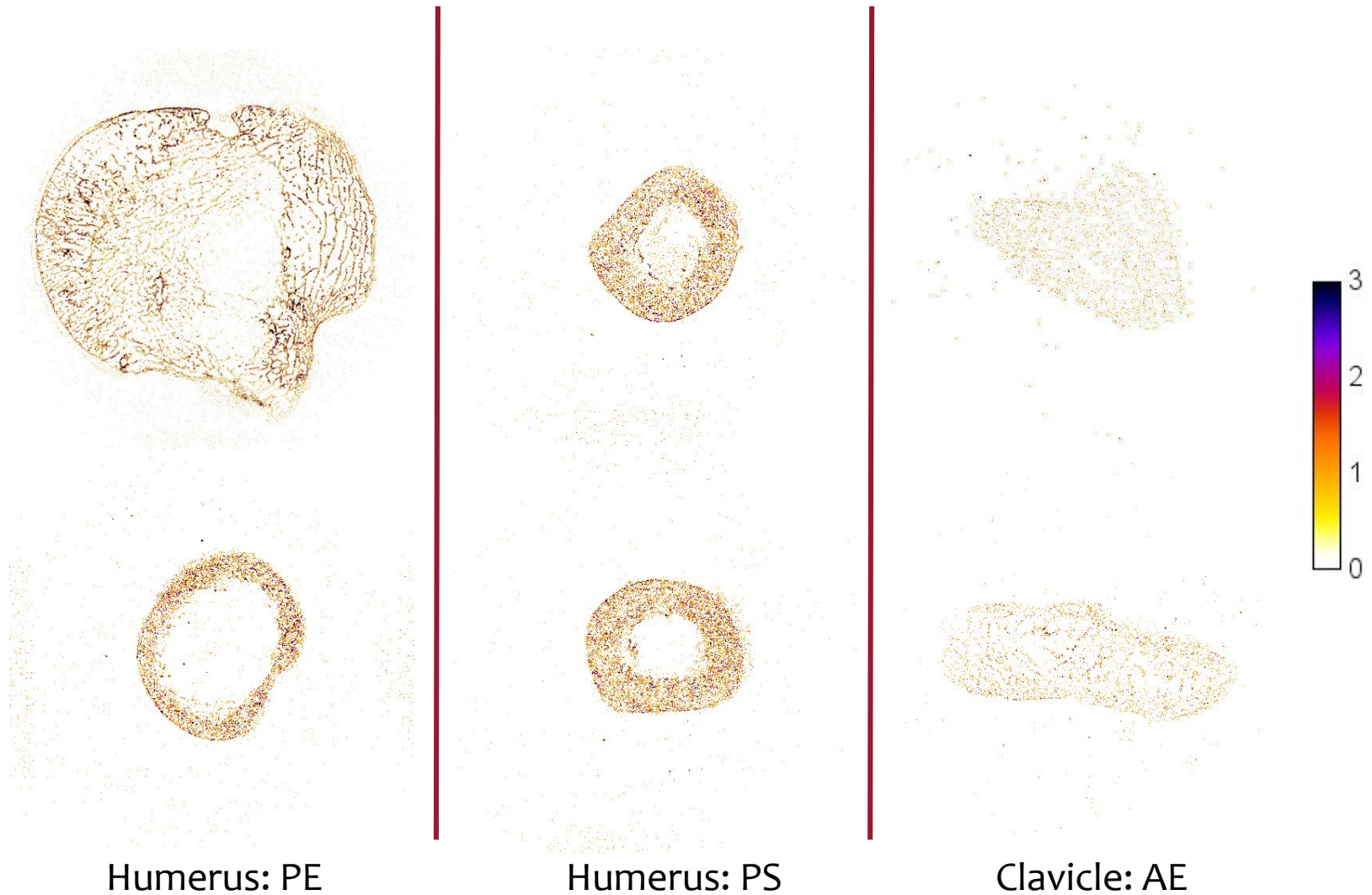
Humerus

PE

1-cm sections
PE & PS

DE

PS

DS

Clavicle

S

LE of AE

SE

ME of AE

Alpha Spectroscopy

- ORTEC: Ensemble and Octête PC systems

- Si(Au) detector: 450 mm^2

- Software: AlphaVision 6.0.4

- Calibration: ^{242}Pu, ^{239}Pu, ^{241}Am (87 dpm, E&Z Analytics)

iQID: Vizualized ²⁴¹Am distribution

Humerus: PE   Humerus: PS   Clavicle: AE

iQID: Surface Activity

- Average surface activity (A_s): ROI based

- Max. A_s : 1 mm^2 binning & max. pixel value (ImajeJ)

Humerus: PE

Pixel size: 1 mm^2
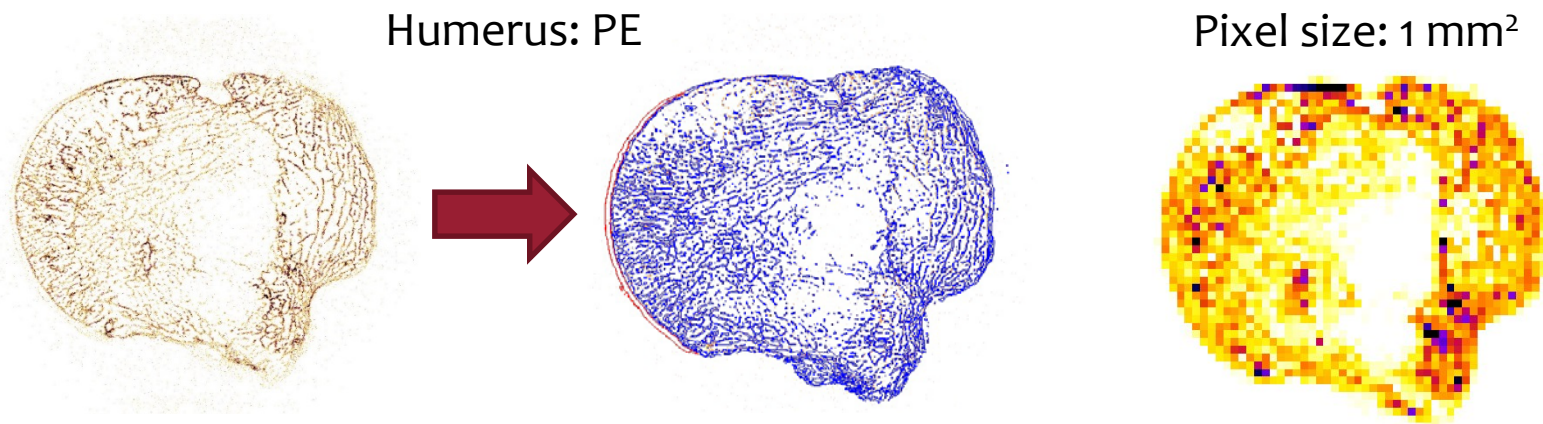
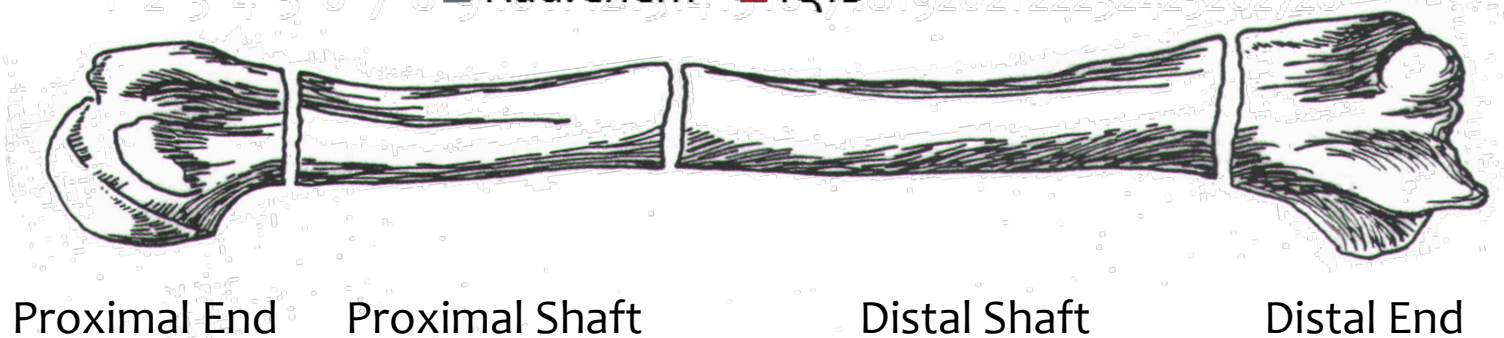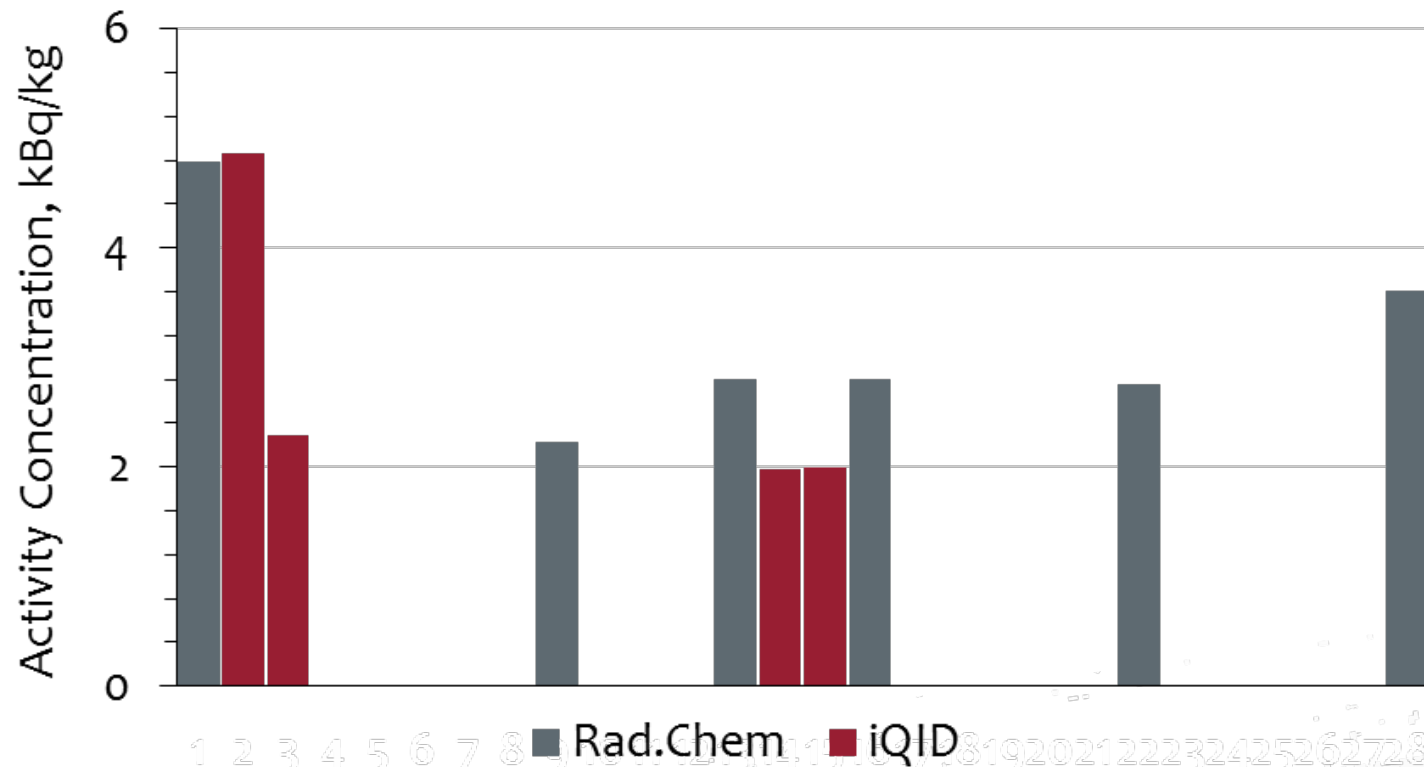| Bone	†Average A_s mBq mm^{-2}	‡Max. A_s mBq mm^{-2}
Humerus		
PE (188-1)	0.198	0.251
PE (188-2)	0.084	0.034
PS (189A-1)	0.074	0.031
PS (189A-2)	0.074	0.028
Clavicle		
AE (1003B-1)	0.057	0.033
AE (1003B-2)	0.033	0.016

† Counts Averaged over original pixel area (816 μm^2 or 389 μm^2 for large and small detectors, respectively)
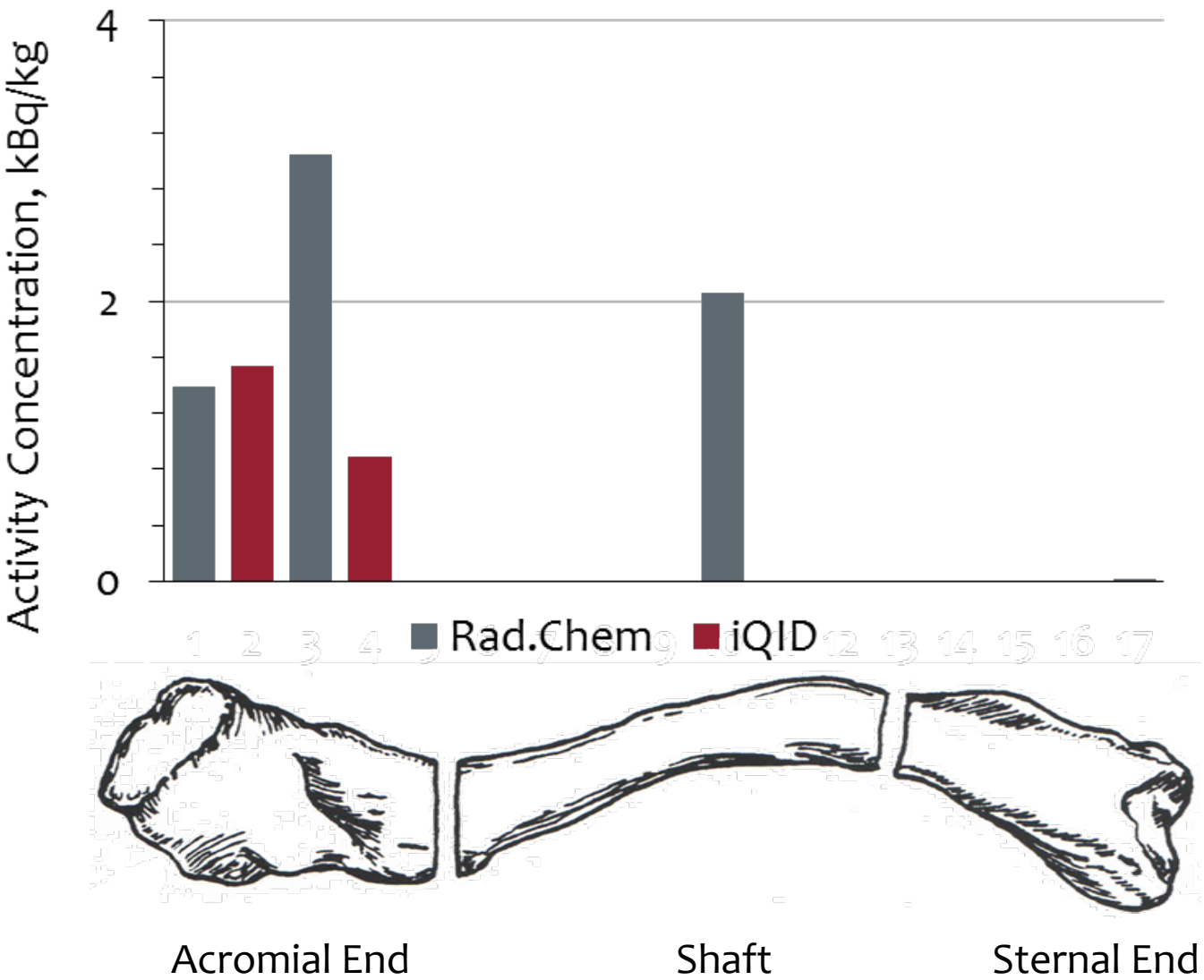
‡ Counts averaged over 1 mm^2 pixel
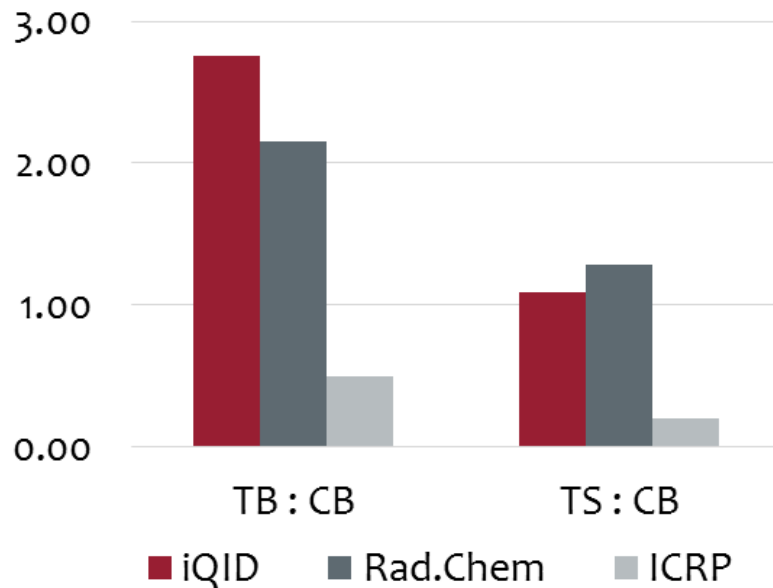
Activity Concentration: Humerus
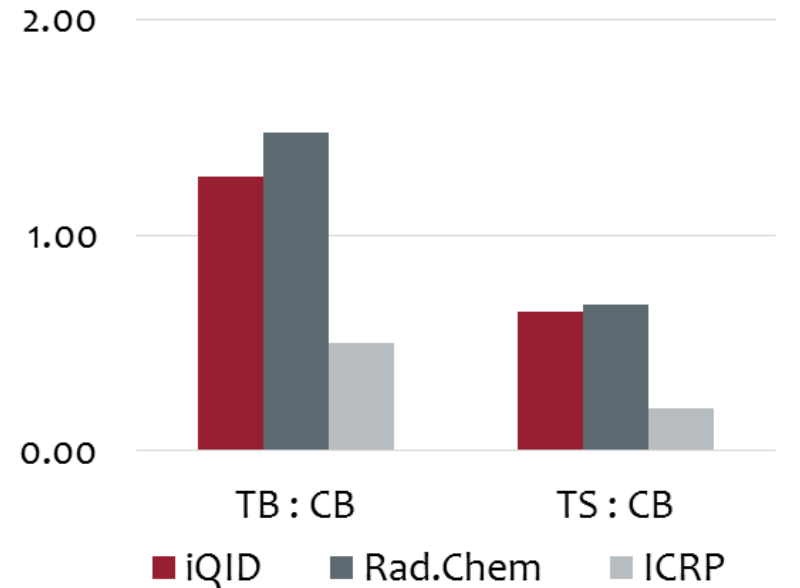
Activity Concentration: Clavicle

iQID: Activity Concentration Distribution

Humerus

Clavicle

Trabecular-to-cortical: 2.5 (humerus), 1.4 (clavicle) vs 0.5 ICRP

Trabecular spongiosa-to-cortical: 1.2 (humerus), 0.7 (clavicle) vs 0.2 ICRP

Conclusions

- ^{241}Am distribution in Case 0846 skeleton was visualized and quantified using iQID within trabecular bone regions

- ICRP defaults underestimate ^{241}Am concentration ratios:

  - ✓ Trabecular-to-cortical: ×5 in humerus, ×3 in clavicle
  - ✓ Trabecular spongiosa-to-cortical: ×6 in humerus, ×4 in clavicle

- Additional bone samples need to be evaluated